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Attribute Matrix Report

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LED Attribute Matrix Report

Introduction

This report for Project 2.1 LED Luminaires for Exterior, Porch and Perimeter Lighting is divided into nine sections. Following the introduction section are explanations of generic control elements, color, and light output. Specific requirements for control, color and visibility are described for residential, commercial, and institutional markets. The last two sections are a brief prototype report for those prototypes currently under development followed by a summary section.

The major unique properties of LED sources are typically listed as follows. It is important to understand and consider these properties during the development of the new LED-based fixtures for this Project.

- Long lifetime
- High durability
- Very low profile
- Highly directional output

Long lifetime: The long lifetime of LEDs typically translates into low maintenance benefits for LED applications. Traffic signals and airport indicators are the usual examples given. Another benefit is the possibility to design fixtures without allowing for the replacement of the source, i.e. the life of the source is greater than or equal to the life of the fixture. This presents the opportunity to design ‘embedded’ systems where the LED source is not removable from the fixture.

High durability: The obvious application that utilizes this quality is the LED flashlight, where impact and physical shock are prevalent. Portable applications in general need to be durable. In the case of permanent fixtures, the weak link will no longer be the LED source, and the entire fixture’s durability will be considered without undue special attention given to the light source.

Very low profile: The low profile nature of LED technology allows LED fixture design and placement in small, hidden, or otherwise restricted spaces too small for other light sources (cold cathode fluorescent lamps and miniature incandescent lamps are two exceptions). The benefits from this property, however, are limited by any secondary optics necessary to alter the distribution or control direct glare from the LEDs. The secondary optics are often necessary, and usually have dimensions greater than the LEDs.

Highly directional output: The light distribution of LED sources is typically contained within 180 degrees, and can be focused into a relatively narrow beam angle with the appropriate chip/lens configuration. This can be an advantage in the design of task lighting, as it reduces the optical engineering necessary to deliver light to a specific area. It can also enable the coupling of the LED light source with fiber optics or light guides, which may lead to novel perimeter lighting methods. One drawback to this approach is the relatively poor efficiency of such coupled systems, which puts a higher lumen requirement on an already lumen challenged technology.

Fixture Control Features

Daylight sensing refers to the ability of an outdoor luminaire to sense the presence of daylight and switch on and off the lamp in that luminaire. A large percentage of commercial and institutional fixtures currently have integrated daylight sensing controls. A smaller percentage of residential fixtures use daylight sensing, as these fixtures can rely more on owner control. The potential energy savings that can result from daylight sensing, in conjunction with the relatively widespread existence of daylight controls, justifies daylight sensing as a requirement for new LED-based fixture systems.

Motion sensing refers to the ability of a luminaire to sense physical movement in a specific zone and change its photometric output. This typically means turning lamp(s) on or changing brightness levels. It has been shown in studies at LBNL that motion sensing can produce dramatic energy savings in applications where long burn hours are seen. Certain outdoor lighting applications with long burn hours are a natural choice for motion sensing controls. Motion sensing can be used typically with incandescent, fluorescent, and LED lamp types.

Dimming refers to the ability of a lamp/control system to deliver a variable amount of light output. Dimming is used commonly with incandescent, fluorescent, and LED light sources and not frequently used with high-intensity discharge type sources in outdoor applications.

A recent (year 2000) survey of 1000 California homes found the following conclusions on the use of exterior residential porch lights:

- Roughly 80 percent of all porch lights use incandescent lamps.
- Just over 6 percent of homes use a CFL (compact fluorescent light).
- Only 15 percent of all porch lights are equipped with some form of control device such as a motion detector, photocell, timer, etc.

This study leads to the conclusion that substantial opportunities for energy savings exist with the proper use of daylight and motion sensing controls.

Color Requirements

Outdoor security lighting generally does not require high CRI illumination. The CRI or color rendering index is a method used to express the color rendering qualities of a light source and is based on a scale up to 100. Other outdoor lighting applications, such as sports lighting or nighttime retail areas, require higher CRI requirements.

The majority of residential and commercial lamps are ‘white’. Within this category, the color temperature (CCT) and color rendering index (CRI) of these sources varies widely, from the relatively low CRI of mercury vapor or high-pressure sodium lamps (CRI = 15-21) to the high CRI of tungsten halogen lamps (CRI = 100).

Lamp colors other than white are possible, and have seen commercial development. One example is the low-pressure sodium lamp: these light sources emit nearly monochromatic light at 589 and 589.6 nanometers (nm). Low-pressure sodium lamps were introduced as extremely efficient sources that provided large energy savings in many outdoor lighting applications. However, the poor color rendering has been an issue and the lamps have not been widely accepted.

Another example of a colored lamp source is the yellow 'bug' light, used in outdoor applications where insects are a problem. Scientific data suggests that insects respond strongly to ultraviolet light, with data also pointing to bright white sources as cluster points for swarming pests. Scientific data notwithstanding, the yellow 'bug' light is a commercially successful source and has been widely adopted for use in outdoor residential fixtures. Other colored sources are available and are predominantly used as decorative or novelty type sources.

Lumen Output and Delivered Lumens

The total lumen output of a fixture is a measure of the light in all directions that a lamp/fixture combination produces. The term 'fixture efficiency' refers to the total lumen output just described divided by the 'bare bulb lumens', i.e. the lumen output of the bare source lamp without the fixture. These two concepts are frequently used to describe the efficiency of a fixture system.

There is an obstacle, however, with using these concepts to describe certain fixture systems: no allocation is made for the direction and distribution of light. With LED systems, it becomes very important to characterize where the light is distributed, and what portion of the output lumens reaches the specific surfaces that are to be illuminated. Thus, the concept of 'delivered lumens' becomes important when characterizing these types of highly directional light systems.

The term, 'delivered lumens', refers to the lumen output of a fixture system onto a specific task plane. For exterior lighting, this task plane is defined as the wall beneath the fixture and the ground adjacent to this wall. The exact dimensions of these surfaces are then defined to meet certain visibility or coverage requirements. In residential applications, this means providing coverage to a front porch or other area in front of the fixture with possible additional coverage to a pathway leading to a door or entryway. In commercial or institutional applications, this means installing multiple fixtures along the side of a building and providing continuous coverage along the line of the building. For commercial and institutional settings, the spacing of the fixtures becomes important in designing the system.

Control Requirements for New LED Fixtures

1. daylight sensing
2. motion sensing with duration and sensitivity adjustments

Any fixture utilizing LEDs as source elements will require an electronic driver to control the light output. This same circuit board can also be designed to perform daylight and motion sensing functions. With the potential of significant energy savings, it becomes reasonable and logical to design LED systems with motion and daylight sensing functionality (provided these functions are not provided elsewhere or present operational problems). The addition of daylight sensing and motion sensing to an LED system will require only a few additional components and circuit board real estate. These added costs should be small considering volume production elements already present in an LED system.

Color Requirements for New LED Fixtures

The lower color requirements of outdoor luminaires, coupled with the wide range of available LED colors, suggests that developing a range of color systems is both practical and appropriate. Recent consultations with a lighting controls manufacturer utilizing LED technology indicated a wide range of customer preference with regard to color. In addition, the importance of scotopic vision under low light conditions will be influenced by the spectral qualities of the LED sources. This suggests that no color restrictions should be applied to new fixture development until laboratory prototypes are built and tested. This process will be facilitated because LED colors can be substituted with relative ease within the control system and can include the entire visible spectrum in the following common dominant wavelengths (in nm) [current lumens per watt estimates lm/w]:

> 635 (red) [>40 lm/w], 615 (red/orange)[>40 lm/w], 605 (orange)[>40 lm/w], 592 (amber)[30 lm/w], 525 (green)[25 lm/w], 505 (cyan)[30 lm/w], 470 (blue)[5 lm/w], 455 (royal blue)[n/a] and white.

Note on WHITE LEDs: Much speculation has taken place on the role of white LED technology in the emerging field of LED illumination. To date, this technology is still in an early development stage, despite what LED marketing or other LED industry professionals may say.

The current leading high lumen output white LED producer, Lumileds, produces a one-watt and five-watt white LED device. These devices have efficacies in the 20-25 lm/w range. However, there are still real concerns about the lifetime characteristics of these devices. Currently, no public information has been released as to the nature of this problem and/or when a solution will be found. Shipment of a long lifetime (>1000 hours) five-watt white LED device has been postponed indefinitely. Tentative plans for long life five-watt devices, as of winter 2002, had shipment occurring at the end of 2003, but no solid commitment has been made.
Another producer of high lumen output LEDs is Osram Opto Semiconductors. They have one-watt yellow and red LEDs that have just been released for production. They have plans also for one-watt white LEDs that are to be available summer 2003, but no samples are shipping yet. Again, they have sited lifetime issues for their white LEDs.

These issues suggest that care be taken in the design of systems that employ high output white LED technology. The field is changing quickly, and today’s best white LED will quite possibly be tomorrow’s lower performing white LED.

Visibility Requirements

Visibility requirements especially at night are affected by various parameters. For detailed information on visibility parameters, it is recommended to reference the Illuminating Engineering Society (IES) Lighting Handbook. Nighttime visibility of an object is a function of several parameters:

- Luminance of the object
- Luminance of the background
- Contrast
- Spectral qualities of object and background
- Size (a function of distance)

Other factors influencing visibility include cognitive factors such as attention, expectation, and familiarity (these are often inverse functions, i.e. increased familiarity will typically mean decreased attention and vice versa). Under low light conditions, edge contrast definition plays an increased role in visibility. Edge contrast is a function of the size and number of sources present as well as the location of these sources. Disability glare will lower visibility by reducing contrast.

The many variables involved with lighting outdoor spaces make attempts to specify absolute luminance or illuminance targets difficult. Luminance values in particular are strongly influenced by the reflective qualities of the surfaces involved. For exterior lighting, these qualities will vary widely depending on the building color, ground composition, number and location of reflective surfaces, etc. Using illumination as a guide, .5 lux is generally considered adequate for a person to navigate obstructions. Laboratory experiments using 60-watt incandescent yellow lights have shown illuminance values in the range of .5 to 7 lux in the area immediately surrounding a fixture mounted at a height of seven feet. This represents the lowest wattage and light output of fixtures currently targeted by this Project, and any LED based fixture should perform to this or higher levels.

In general, lamp/fixture outputs currently in use in the application areas under consideration can serve as the baseline minimum performance criteria for novel LED approaches. This does not necessarily mean that the LED output should match that of the ‘currently in use’ fixture, only that the LED system be able to provide the same level of user performance as the ‘currently in use’ fixture. As an example, a system of ‘currently in use’ fixtures that provides pathway illumination from pedestal type light fixtures could theoretically be replaced by an LED/fiber optic system that illuminates and defines the edge of the pathway without casting light directly onto the path surface. Other factors of visibility would obviously need to be addressed by the new system, but a requirement to directly replicate the output and distribution of the ‘currently in use’ system is not necessary.

Prototype Report

Initial prototype development has concentrated on the residential exterior porch-type light fixture. Radiance computer models based on traditional ‘lamp up’ and ‘lamp down’ porch fixtures have been developed to form a baseline for LED fixture designs (figure 1).

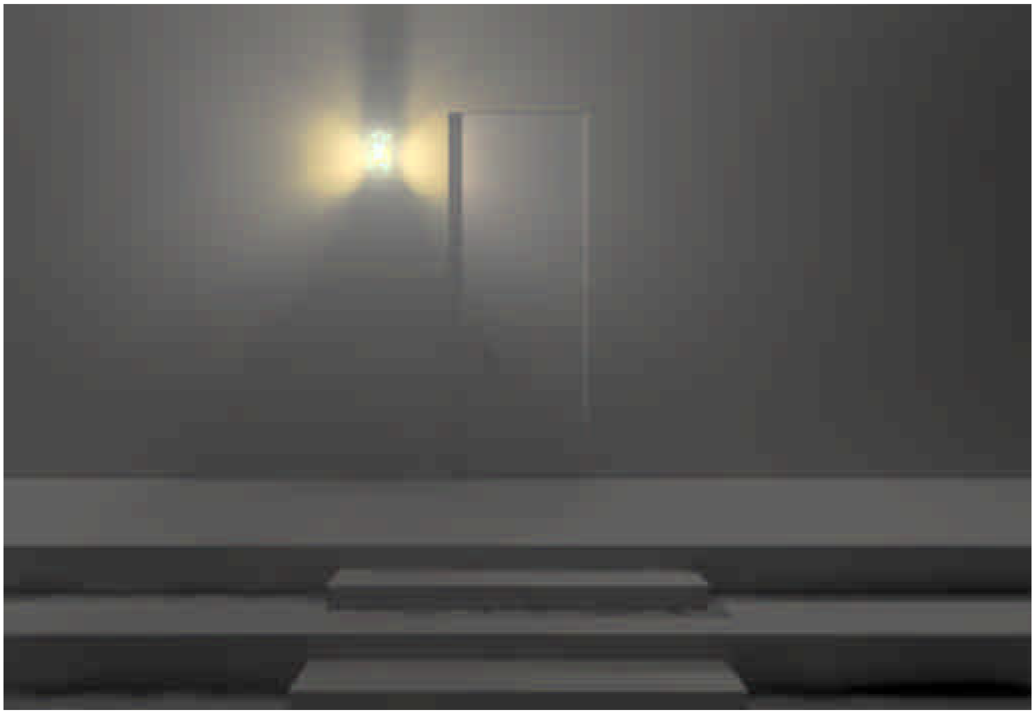

Figure 1. 'Lamp up' style residential porch light Radiance model

Specific illuminance data can be draw from these simulations with false color imaging (Figure 2). False color plots use different colors to display different levels of information, in this case different light levels.

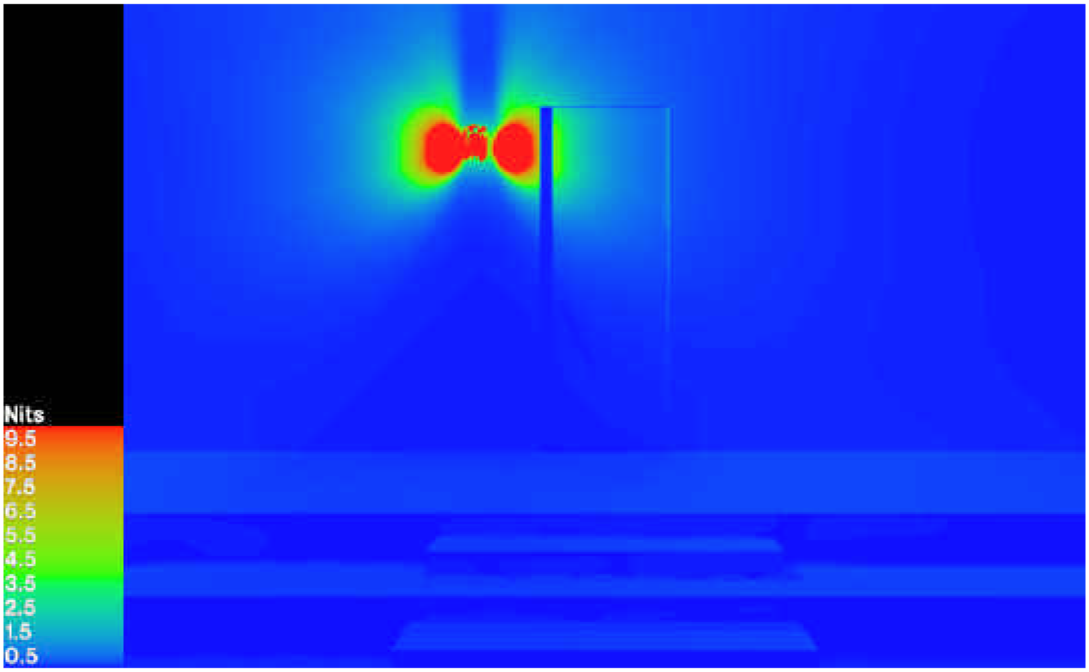

Figure 2. False color data plot

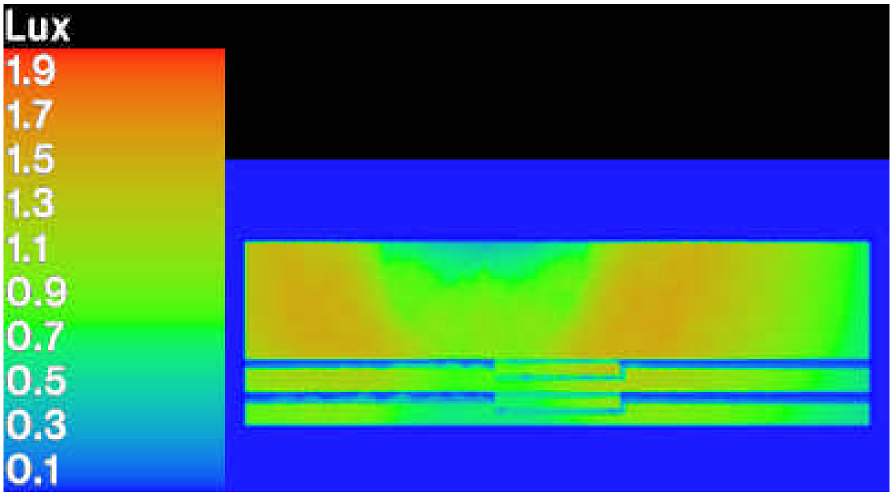

Figure 3. Plan view with false color lux data

Analysis of this baseline data yields specific illuminance goals for novel LED-based fixtures. Initial tests have shown that these illuminance levels can be achieved with just three high-output LEDs. This is an encouraging result and could lead to cost-effective consumer LED-based fixtures.

Summary

Presented below is a summary matrix for residential, commercial, and institutional applications that covers the technical requirements (i.e. control, color, and illuminance) that are known at this time for LED-based fixtures.

	Residential	**Commercial**	**Institutional**
Control	Motion/daylight	Daylight	Daylight
Color	Any	White, yellow	White, yellow
Illumination	Low (<100 lumens)	High (>1000 lumens)	Medium/High (100-1000 lumens)
Cost	Low	High	Medium/High
Energy * savings	200 kW hr/year/ fixture	Unknown	Unknown
Maintenance benefit	Low	High	High
Payback *	3-5 years	Unknown	Unknown

* Energy savings and payback periods based on five-watt LED fixture versus 60 watt incandescent with an average 10 hour run time per night based on 0.12 $/kWhr with LED fixture cost of $60 to $100.

The aesthetic requirements for the residential market will be the highest of any of the market sectors. This, combined with the very wide range of fixture styles in this sector, makes the design of an LED fixture difficult at best. To address this issue, LBNL is focusing on an LED fixture design that will be used in conjunction with any standard porch light fixture. This will enable not only retrofit with existing fixtures, but also the selection of any standard fixture in new construction to match a specific décor. The details of this new design will be outlined in the Matrix of New Concepts.

Additionally, initial input from the Program Advisory Committee for this Public Interest Energy Research Program suggested that commercial and institutional LED-based fixtures could be more cost-effective than residential because more outdoor lights are typically used per site and maintenance cost savings could be significant. Also, color and aesthetics may not be as big a factor for the institutional market. LBNL intends to evaluate these markets as soon as possible and establish the relative cost-effectiveness.

Other prototype fixture results will follow during the Concept Development Phase of Project 2.1 LED Luminaires for Exterior, Porch and Perimeter Lighting.